LEACHING OF APPLE FOLIAGE BY RAIN

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SUMMARY

The paper contains the results of analyses of rainwater collected under apple-trees during 1954. The amount of constituents leached totalled (exclusive of the constituents found in rainwater):

potassium	25–30 kg per hectare
sodium	9.0 ,, ,, ,,
calcium	10.5 ,, ,, ,,
organic matter	7.4 ,, – equivalents $KMnO_4$ per hectare

In the same period the amount deposited by rain was

potassium	1.7 kg per hectare
sodium	9.5 ,, ,, ,,
calcium	3.8 ,, ,, ,,
organic matter	4.0 kg-equivalents $KMnO_4$ per hectare

The consequence of leaching is discussed mainly in relation to
soil conditions,
foliar analyses,
tree and fruit growth.

INTRODUCTION

The supposition that leaves lose some of their soluble constituents by the percolating action of rain is undoubtedly rather old, but investigations in this respect have been few and far between.

The possible loss of nutrients due to the leaching effect of rain has been considered mainly in connection with the senescence of leaves (WEHMER 1892 [16]) and here and there in literature one may find observations on the striking differences in composition and behaviour of the same plant growing in the open and in the greenhouse – e.g. COUNCLER [4] and MANN [11]. The latter, investigating apple tree nutrition, found that small brown spots (Cox's Orange spots) occurred on the leaves of trees in the field, but not in the greenhouse. In 1925, MANN and WALLACE [12] attributed these spots to the leaching effect of rain-water. In fact, they showed that the treatment of fresh and healthy detached leaves with cold distilled water caused such spots to appear and at the same time it was found that the distilled water extracted from the leaves most of their potash content and an appreciable amount of organic matter. Several years later, in 1930, WALLACE [15] found that the soluble constituents from detached apple and gooseberry leaves were more easily extracted by distilled water than they were from pear, plum and black-currant.

CHOLODNY, in 1932 [3], found sugar in artificial 'rain-water' collected from wheat plants, and he considered the decrease in yield of grain after prolonged rain to be due to the leaching of sugar from the plants by the rain. He also indicated that the flavour of strawberry and other fruit deteriorated in bad weather as a direct result of the loss of sugar caused by rain.

On account of analysis of dew collected from leaves, and of extraction experiments with leaves of many plant species, ARENS in 1934 [1] postulated an active excretion of different substances from leaves (Kutikular Exkretion). His view was supported by the work of LAUSBERG in 1935 [7]. ENGEL, in 1939 [5], could not accept the idea of an active excretion, but favoured the supposition of a diffusion of leaf-substances in rain-water.

INGHAM [6] recently compared the composition of open field rain with rain drops from trees, and found that the rain from trees contained six times the amount of P_2O_5 and 3–4 times the amount of CaO and NH_4-N contained in the field rain. From rain-water collected under spruce and pine, oak and birch, TAMM [14] found considerable amounts of K, Ca, Na and organic matter, and lesser amounts of N and P. During a period of forty days in the autumn, 2–3 kgs per hectare of the elements K, Na and Ca were carried to the ground by rain from spruce and pine.

METHODS AND MATERIALS

Inspired by the paper of TAMM, and with an eye to the differences also found at this station in the behaviour of greenhouse cultivated trees and field grown trees, we found it of great interest to investigate the amount of nutrients leached from apple trees by rain. Starting in 1951 with occasional analyses of rain-water, we have since extended our work to comprise a full year account of the composition of rain-water collected under apple trees as compared with the composition of rain-water collected in the open field, and the results presented here are those obtained in 1954. To avoid ambiguity, rain-water collected under trees will hereafter be termed 'leaching-water', and the term 'rain-water' will be used for that collected in the open field.

The investigations were restricted to the elements K, Na and Ca, together with organic matter estimated as the amounts of $KMnO_4$ consumed by leaching-water and rain-water. The elements were determined by means of a Beckmann flame-spectrophotometer.

Leaching-water and rain-water were collected in containers comprising a flat, painted iron funnel connected to a one-liter pyrex flask by means of a rubber stopper with two borings. A filter was inserted between the funnel and the flask.

Frequent attention was necessary to prevent contamination of the water by dust and litter. The water was collected under 2 thirty-five year old trees of the variety Bramley's Seedling, and 3 of Cox's Orange Pippin, all on seedling rootstocks. The trees were healthy and vigorous and stood in grass on a rather heavy, fertile soil with clayish calcareous subsoil. The Bramley trees were not subjected to spray treatment, but the Cox's Orange were sprayed with the normal range of spray-materials including Bordeaux-mixture, lime sulphur and wettable sulphur combined with insecticides.

The weather was rather warm and dry until July, when it became unusually wet and cold and these latter conditions were maintained.

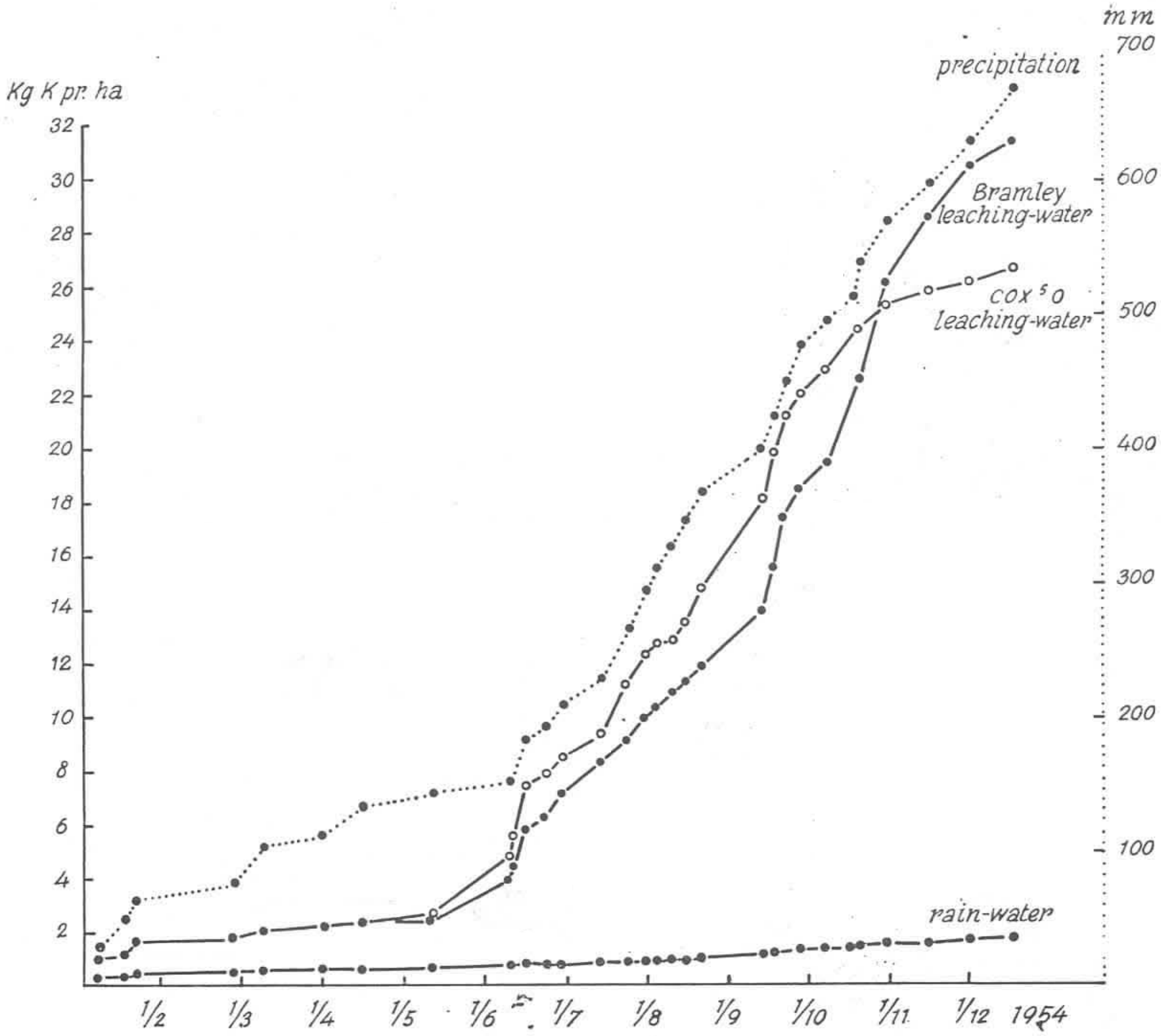

FIG. 1. Potassium deposited by precipitation during 1954

In the results presented here, the figures for organic matter and calcium in respect of Cox's Orange have been omitted, while the figures for sodium are average for all trees, and the figures for potassium have been stated separately for each variety.

All figures stated have been calculated on the basis of one hectare of planted area, and on the assumption that the whole amount of precipitation reached the ground. In practice, of course, this condition is not fulfilled, as part of the precipitation is lost through the evaporation of rain in the tree tops. It is, however, difficult to estimate the loss by evaporation, as the distribution of the precipitation on the ground is extremely uneven (McMUNN [13], LINSKENS [9]), but this may be valued at between 10 and 20 per cent. of the total precipitation.

RESULTS

The total amounts of leaf components carried to the ground by leaching-water and rain-water during 1954 are shown in table I.

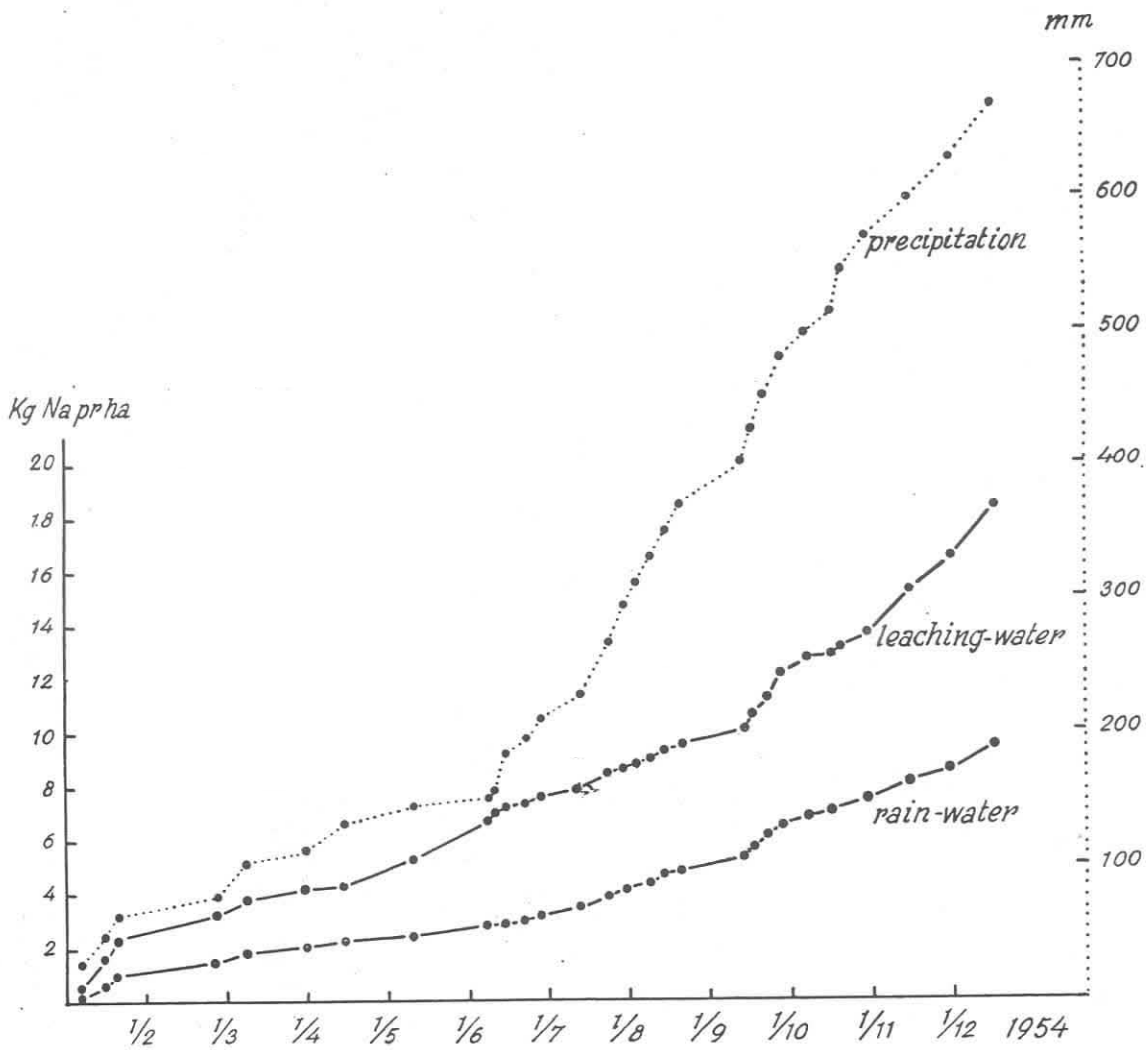

FIG. 2. Sodium deposited by precipitation during 1954

TABLE I. Amounts of leaf components leached from apple trees by rain during 1954, calculated per hectare of tree-covered area

Source	K kg	Na kg	Ca kg	Organic matter kg-equivalents $KMnO_4$
Bramley Seedling . . .	30.0	9.0	10.5	7.4
Cox's Orange	25.0	9.0		
Rain-water	1.7	9.5	3.8	4.0

The figures are also shown in figs. 1–4. (Summation-curves showing the amounts of potassium, sodium, calcium, and organic matter carried down by rain during 1954, and curves showing the amounts of precipitation in the same period.)

Potassium: The total amounts leached were 30 kgs from Bramley's Seedling and 25 kg from Cox's Orange Pippin. In spite of the lesser amount leached from Cox's Orange, the rate of leaching was apparently somewhat faster. Remarkable amounts were

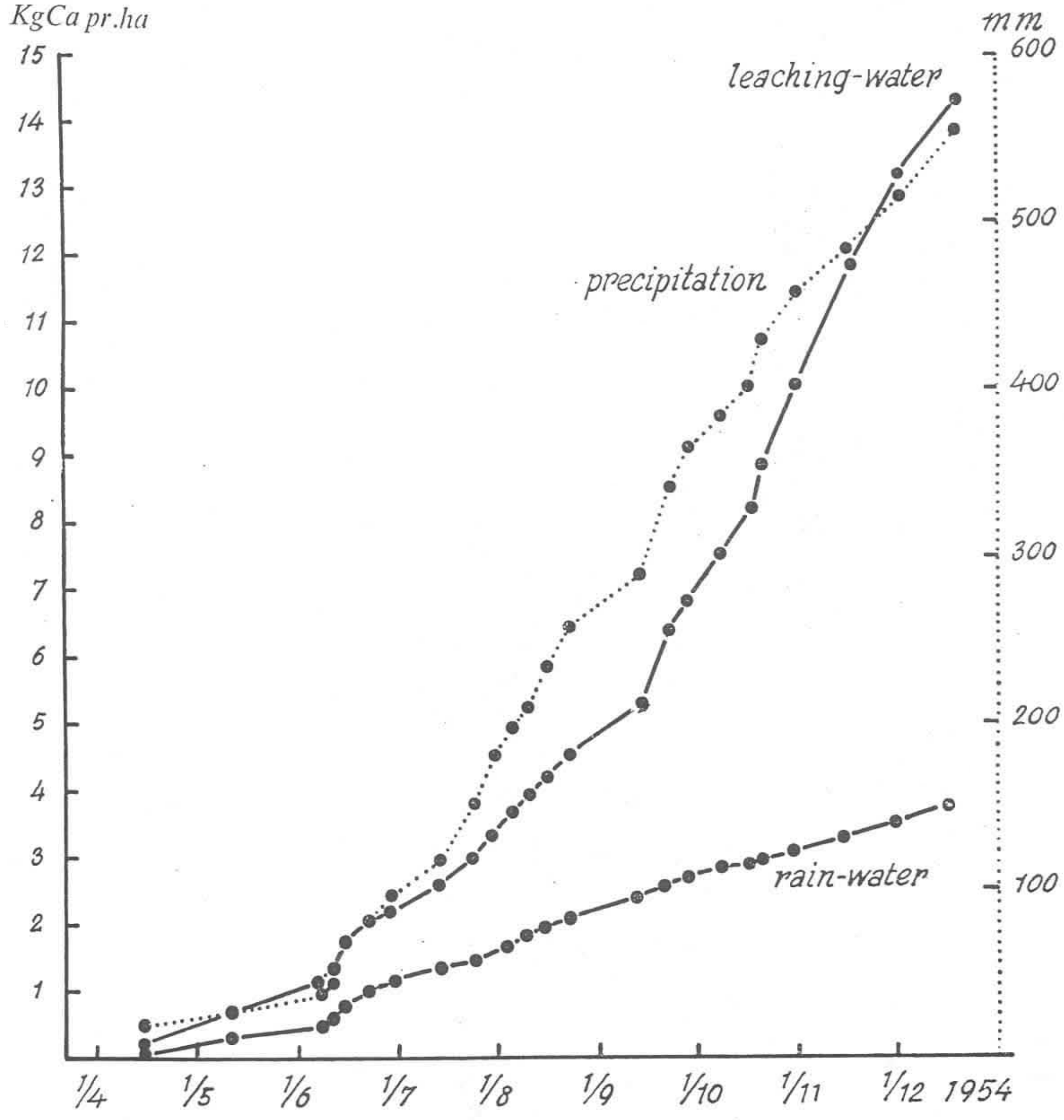

FIG. 3. Calcium deposited by precipitation during a part of 1954

leached during the dormant period of the trees. The amount leached seemed to be a function of the amount of precipitation.

Sodium: The rate of leaching was fairly steady throughout the year and the amount leached totalled only double the amount deposited in the earth by rain-water.

Calcium: The rate of leaching was somewhat slow until the autumn, but increased remarkably during the senescence of the leaves.

Organic matter: During the dormant period, the rate of leaching was fairly steady, but at the time of flowering it increased abruptly and continued at a faster rate, reaching a new maximum in the autumn.

If a conversion factor of five is used to estimate organic matter from $KMnO_4$, the

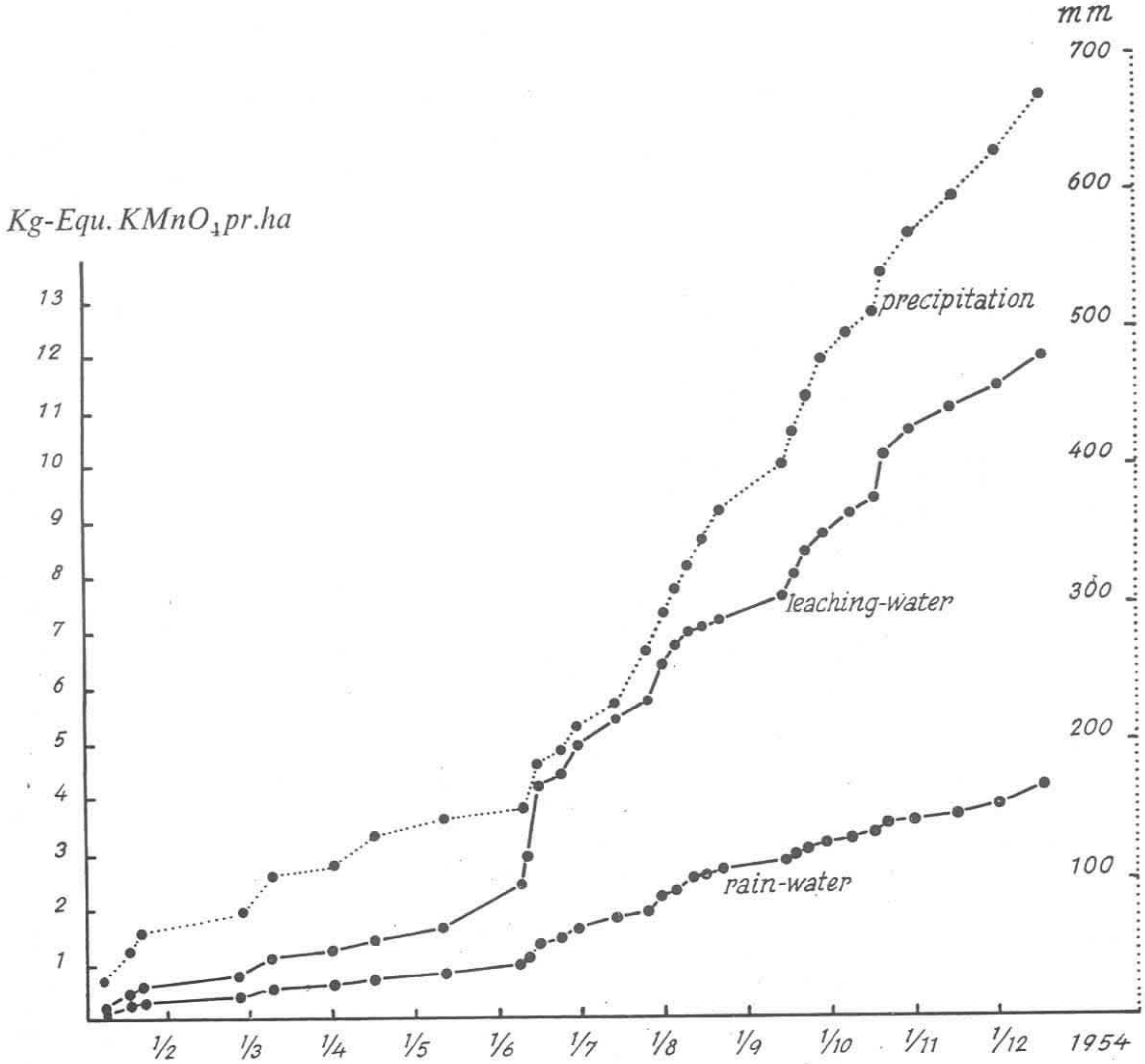

FIG. 4. Oxidizable substances deposited by precipitation during 1954

amount of organic matter leached from the trees corresponds to more than one ton per hectare. There is reason to suppose that the nature of the reducing substances of leaching-water and rain-water differ. The residue left by evaporated leaching-water was brown and sticky with a distinct smell of apple-leaves – most of it is likely to be carbohydrates. The residue from rain-water was similar to salt.

DISCUSSION

The soluble components leached may be of different origin, part of them being derived from the trees, part of them originating from impurities such as dust, pollen-grains, fungus spores, excrements of birds and insects, adhering or adsorbed to the surfaces of leaves and twigs.

It should be possible to distinguish the two sources by means of the following reasoning:

If the constituents are derived from the trees, the total amount leached will primarily be a function of the amount of precipitation, as it is the rain which extracts the substances from the leaves.

If, on the other hand, the materials originate from impurities, the quantity carried to the ground will primarily be a function of time.

By examining the figs. 1–4 it can be seen that the amounts of potash, calcium and organic matter resulting from leaching, closely follow the amount of precipitation, while this is not the case with sodium. It may therefore be a reasonable presumption, that the greater part of the potassium, calcium and organic matter was derived from the trees, whereas most of the sodium originated from impurities.

POSSIBLE CONSEQUENCES OF THE LEACHING PHENOMENON

It may be assumed that the component substances of leaching-water have various influences on the soil under trees. On a clayish soil the ions will accumulate in the top-layer of the soil, and the amount of exchangeable potash will gradually increase to such an extent, that misleading information on the nutritional condition of trees can be gained from analyses of the top-soil sampled under the tree tops.

The large quantity of soluble organic matter, carried to the ground by the leaching water, is without doubt of consequential influence on the micro-organisms in the soil under the trees.

It is also possible that the texture of the soil is changed by the leaching-water, as it was recently shown (BLOOMFIELD [2]) that leaf-leachates have a deflocculating effect on kaolin.[1]

If the migration of potassium into the leaves takes place more slowly than the rate of potash-leaching from the leaves, then the potash content must decrease; hence the actual potash content is dependent upon the migration rate in the plant-organs as portrayed in the following scheme:

twig ⇆ leaf → rain-water.

The leaching phenomenon must, therefore, also be taken into consideration in judging the results of leaf-analyses.

The causality of leaching with regard to deficiency symptoms has not been entirely established, but in our opinion the influence of the leaching rain on the development of deficiency-symptoms cannot be neglected.

There is reason to believe that the widely fluctuating potash content of leaves, found during examinations in the growing season, may be due to the leaching-effect of rain.

If the mineral composition of leaves is compared from year to year, the potash content may vary widely, and we feel that leaching is here involved.

As fruit size and tree-growth are adversely affected by shortage in potash, spraying with potash-compounds might be recommended as a means of counteracting the loss by leaching in wet periods.

According to LINSKENS [9] the leaves are not wetted by water to the same extent in different stages of the ontogenesis, being more hydrophobic in the younger than in the older stages. As a close contact between water and leaf should be a condition for the leaching effect of water, it may be possible that the trees are not subjected to leaching to the same extent in the different stages of development.

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[1] After the congress I noticed the work of LUTWICK & JONG: 1984, 'Leachates from decomposing leaves, II, Interaction with soil forming materials'. Canad. Journ. Agric. Sci. **34**: 203–13.

Surface active agents change the wetting properties of the leaves (ZIEGENSPECK [17], LINSKENS [9]) and may therefore influence the degree to which the leaves are leached, and as spray-materials often contain surface active ingredients, this must be taken into consideration when the influence of spray-materials on the trees is determined.

REFERENCES

[1] ARENS, K., 1934. Die kutikuläre Exkretion des Laubblattes. ahrb. wiss. Bot. **80**, 284–300.

[2] BLOOMFIELD, C., 1954. The deflocculation of kaolin by tree leaves leachates. Trans. Fifth Int. Congr. Soil Sci. **2**, 280–83.

[3] CHOLODNY, N., 1932. Zur Kenntnis der durch das regnerische Wetter verursachten Ertragsabnahme bei Getreidearten. Ber. d. bot. Ges. **50**, 562–570.

[4] COUNCLER, C., 1883. Aschengehalt der Blätter in Wasserkultur gewachsener Bäumchen, verglichen mit demjenigen auf festem Boden erwachsener. Landw. Versuchsstat., **29**, 241.

[5] ENGEL, H., 1939. Das Verhalten der Blätter bei Benetzung mit Wasser. Jahrb. wiss. Bot., **88**, 816–61.

[6] INGHAM, G., 1950. Effect of materials absorbed from the atmosphere is maintaining soil fertility. Soil Sci., **79**, 205–12.

[7] LAUSBERG, TH., 1935. Quantitative Untersuchungen über die kutikuläre Exkretion des Laubblattes. Jahrb. wiss. Bot., **81**, 769–806.

[8] LINSKENS, H. F., 1951. Über die Änderung der Benetzbarkeit von Blattoberflächen nach Spritzungen. Z. Pflanzenkrankh. **58**, 327–32.

[9] ———, 1952. Über die Änderung der Benetzbarkeit von Blattoberflächen und deren Ursache. Planta, **41**, 40–51.

[10] ———, 1952. Niederschlagsverteilung unter einem Apfelbaum im Laufe einer Vegetationsperiode. Ann. der Meteorologie, 30–34.

[11] MANN, C. E. T., 1924. The physiology of the nutrition of fruit trees I. Ann. Rep. Long Ashton Res. Sta. **1924**, 30–45.

[12] ——— & WALLACE T., 1925. The effect of leaching with cold water. Journ. Pomol. Hort. Sci. **4**, 146–61.

[13] MCMUNN, R. L., 1936. The distribution of rain under an apple-tree. Proc. Am. Soc. Hort. Sci. **33**, 95–98.

[14] TAMM, C. O., 1951. Removal of plant nutrients from tree crowns by rain. Phys. Plant., **4**, 184–188.

[15] WALLACE, T., 1930. Experiments on the effect of leaching with cold water on the foliage of fruit trees. Journ. Pomol. Hort. Sci. **8**, 44–60.

[16] WEHMER, C., 1892. Die dem Laubfall vorausgehende vermeintliche Blattentlehrung. Ber. d. bot. Ges., **10**, 152.

[17] ZIEGENSPECK, H., 1942. Zur physikalischen Chemie unbenetzbarer, besonders bewachster Blätter. Kolloidzeitschr. **100**, 401–3.

DISCUSSION

The actual concentration of the elements in the leachate

The leachate contained 5–20 ppm potassium, 1–4 ppm sodium and 1–4 ppm calcium (H. EVANS, British Guyana).

The influence of dissolved nitrogen

The possible influence of dissolved nitrogen in rainwater on the leaching of various elements has not been investigated (S. ÖZBECK, Turkey).

The leaching of potash during a rain period

In some cases the potash content in the leachates was higher at the beginning of a long rain period than later, but this was not always the case (TH. RAPTOPOULOS, Greece).

Spraying with K

Spraying with 1 % K_2SO_4 on apple trees was performed some years ago, without visible scorching of the foliage and with apparently good effect (F. A. ROACH, U. K.).

Experiments with radioactive isotopes

Using radioactive isotopes, Dr. H. B. TUKEY (U.S.A.) found that as much as 71 % of certain nutrients were leached out from the leaf in 48 hours of continuous mist.

Effects of leaching

There are as yet no indications that leaching has a damaging effect on e.g. flower initiation of fruit trees (T. VISSER, Netherlands).

A possible distinction between day and night leachates

So far day and night leachates have not been separated. Dr. L. K. WIERSUM (Indonesia) remarks that there are indications that the retentive capacity of the leaf may be quite different during day and night.

The effect of spray irrigation

A leaching by artificial precipitation, i.e. spray irrigation is very likely to occur, but has not been investigated (E. J. WINTER, U.K.).

The distinction between substances of different origin

In these experiments it was not practicable to separate the amounts of substances deposited during periods without rain, from the amounts leached out from the leaves. But, as the amounts of K, Ca, and organic matter carried down with the leaching water was proportional to the amount of rain, whereas the amount of sodium was not proportional to the amount of rain but to the time elapsed, it was thought safe to suppose that the main part of the first mentioned substances originated from the trees, whereas this was not the case with sodium (M. ZWINTZSCHER, Germany).